551.556.3 : 631.67(540)

COMMENTS ON 'UTILIZATION OF WIND ENERGY FOR IRRIGATION IN INDIA' by *A. Jagadeesh et al.*

1. Estimates of *wind energy potential* have been given for a few States in the Indian sub-continent by A. Jagadeesh *et al.* (1982). The assumptions made by the authors in respect of the factors involved in arriving at the estimates are discussed in the present note and the estimates are proved as over-estimates. A more realistic approach is suggested for expressing wind energy availability.

2. For computation of the "annually extractable energy", the authors have used the equation :

$E_a = 0.6 v^3 \times$ (energy pattern factor) $\times$ (overall efficiency of the windmill) $\times$ (Total No. of hours in the year, *i.e.*, 8760) $\times$ (Total rotor area of the maximum number of windmills that can be installed in a region) (1)

'v' being the annual mean wind given by the India Meteorological Department for its surface observatories (1966). The assumptions of the authors are discussed below in the order they appear in the relationship (1), and the fallacies pointed out.

2.1. The *annual mean wind* is normally used only to describe the wind regime by demarcating the country as a whole into regions of strong and weak winds before considering promising regions for a more detailed study. ". . . . the most essential information required when considering the energy potentialities of a site or a district is the *annual duration of wind speeds of different magnitudes*, presented in the form of velocity-duration and power-duration curves" (Golding 1976).

Annual duration of calm spells is important as the windmill remains idle without any contribution to the energy recovery. The annual percentage of winds under 4 mph (*i.e.*, 6.4 kmph or 1.8 mps) increases steeply as the annual mean wind decreases (Fig. 1). For an annual mean wind of 7 mph (11.2 kmph or 3.1 mps) this percentage is as high as 30%. There are a large number of locations in India where the annual mean wind is around this value.

Therefore, detailed estimates of 'available energy' based *only* on the mean wind, are likely to be overestimates by a significant percentage, particularly for areas where the annual mean wind speed is not sufficiently high.

2.2. The Energy Pattern Factor (EPF) in relationship (1) is given by the ratio :

$$\int_0^T v^3\,dt \Big/ T\left(\frac{1}{T}\int_0^T v\,dt\right)^3$$

'v' being the wind speed at any time and 'T' is the total time considered. The significance of the EPF is that the actual total energy obtained from the wind with a continuously fluctuating speed, as is the case in nature, exceeds that calculated by cubing the mean wind speed for any given period.

EPF values for long periods (T = one month or a year) varies from a minimum of 2.2 to a maximum of 4.5 for low wind speeds of around 1.5 mps and tends to be slightly only more than unity as the wind speed increases to 8 mps (Fig. 2). For short periods, it does not vary over such wide limits, nor is it much greater than unity (Golding 1976). Yet Jagadeesh *et al.* have arbitrarily applied EPF values varying from 2.0 to 5.5 for different States, as shown below assuming the value to be uniformly the same over the entire area of the State, for low as well as high wind speeds (which is how the wind varies in the course of the day). The values shown below have been taken from the detailed papers of the authors published elsewhere.

State	EPF value used	Remarks of the author of the present note
Gujarat	2.3	
Kerala	5.5	Value found for Bangalore and assumed valid for coastal stations in Kerala
Maharashtra	2.8	
Madhya Pradesh	2.3	
Orissa	4.3	
Tamil Nadu	4.0	Value found at Kodaikanal

The EPF is an uncertain parameter and introduces a variable error in the estimates from place to place. By omitting this factor altogether, one errs only on the safe side and yet can present a useful picture.

2.3. The overall efficiency of energy extraction by the windmill assumed as 10% by the authors, is a reasonable value taking into account all factors involved.

2.4. The factors in the relationship (1) considered so far relate to the effective wind energy flux in watts/sq. m of a passing airstream in relation to a low efficiency conversion device such as the windmill. This multiplied by 8760, the No. of hours in a year gives the watt hours/sq. metre of a windmill rotor area; the result represents the power which can be extracted from the wind by installing suitable windmills with matched loads.

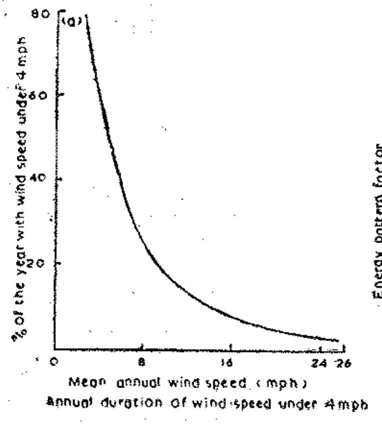

Fig. 1. Annual duration of wind speeds under 4 mph

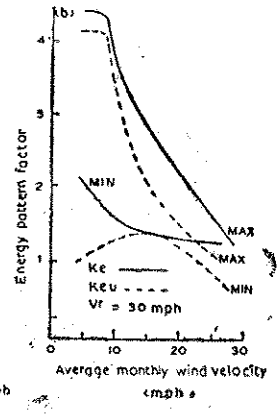

Fig. 2. Energy pattern factors

2.5. When installing a number of windmills, a certain minimum distance has to be kept between adjacent ones for aerodynamic reasons. For an unlimited array of windmills a mean distance of 30 rotor diameters has been found to be the minimum separation without significant loss in the output of an individual windmill (WMO 1981).

The last factor in Eqn. (1) takes care of this requirement and means that if windmills are erected *all over the State at intervals equal to* 30 *rotor diameters*, the forested areas being excluded, it is possible to harvest a wind power estimated by Jagadeesh *et al.* given in Table 2 of their paper as the annual extractable wind energy for the State. Considering the district of Greater Bombay, for example, for which the annual extractable energy has been estimated by the authors (1982) as 0.35×10^9 kwh, approximately 25,000 windmills with a rotor diameter of 10 m are required to be installed, evenly spaced at 300 metres from each other.

This is obviously impossible, as densely populated or built up areas, those utilized fod other purposes or inaccessible, have necessarily to be left out. Practically feasible number of windmills, consistent with aerodynamic and aesthetic considerations, at or very near the user locations (remembering that the windmills are for irrigation) will be a very small percentage of the number calculated in the earlier paragraph.

Thus, the term 'wind energy *potential*', in relation to its ultimate utilization should only express the energy which *can possibly be extracted from the wind, utilising a reasonable and practical number of wind energy conversion devices*, and not give just a theoretical figure unrelated to reality.

3. A number of windmills have been mentioned by the authors in para 2.5. The authors have not stated whether the ORP-TOOL, ANILA or the NAL windmill enthusiastically recommended by them can survive the high winds experienced by the 100 km coastal belt of Orissa, Andhra Pradesh and Madras during the cyclones which ravage these States frequently. This important factor has to preclude quite a considerable area from the wind energy estimate.

4. In order to utilize low wind speeds, the authors have suggested, acceleration of the wind over an

artificial escarpment but the implementation of this plan is not so simple as they have described for the following reasons :

—in a large number of locations, wind direction changes with the season; in some places almost by 180 degrees.

—the normal spacing requirement to be fulfilled will necessitate very long escarpments which may not be economically feasible.

5. In conclusion, while admitting that wind energy has a definite future in India, it is felt that estimates given by Jagadeesh *et al.* are gross over-estimates.

It is felt that any wind estimate should specify either the 'available energy' in the wind at given locations or the anticipated output from a windmill of given specilcations at given locations.

While planning the augmentation of wind speed by providing escarpments, the seasonal change of wind directions should be taken into account; natural escarpments with favourable wind directions in the major part of the year, should be looked for.

The suitability or otherwise, of the different windmills to different areas of the country should be studied and spelt out.

Over generalized estimates of "wind energy potential" over wide regions, based on long term mean winds are likely to mislead the country's planners and windmill manufacturers besides causing disillusionment to the ultimate user because of the use of a windmill not suited to his locality.

6. The author would like to express his thanks to the Tata Energy Research Institute, Bombay for providing a collection of wind energy references.

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D. V. SUBRAMANIAN

Regional Meteorological Centre,
Bombay

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